Answers to reviewers of the Biogeoscience Manuscript (bg-2012-547) "Limitations of microbial hydrocarbon degradation at the Amon Mud Volcano (Nile Deep Sea Fan)" by J. Felden et al.

Reviewer #2:

Reviewer 2: This study is centered on resolving the question of why the activity of anaerobic hydrocarbon degraders in the mud volcano center is low, despite high energy supplies, i.e. the availability of electron donors (methane) and acceptors (sulfate). Through de- scribing the biogeochemical setting in detail, the authors pose several hypotheses, and test them with the available data and kinetic considerations. They eventually conclude that the recent heat and mud expulsion was too soon for the AOM microorganisms to colonize and reflect their biogeochemical potential. On the other hand, the authors conclude that in the periphery of the mud volcano center hydrocarbon transport limits the biogeochemical AOM activity. There are two main positive aspects of this work: First, the data are of utmost quality and are from a newly explored environment. The dynamics of this type of seafloor environments are crucial to understand how the seafloor-ocean interface regulates fluxes of key greenhouse gases, such as methane. Second: The discussed hypotheses are interesting and the authors satisfactorily substantiate their choice of one of these hypotheses. Thus, this well-written biogeochemical account of a mud volcano environment deserves publishing after minor-moderate revision.

Still, a few improvements are possible. I am aware that the study of short-term (days- weeks) dynamics may not always be possible in deep-seafloor studies. However, I am not sure about the changes between 2006-2009 are due to some long-term dynamics. Not much can be done in this respect since the authors present no data, but local spa- tial variation and some possible short-term temporal changes need to be discussed. At least, the comparisons between 2006 and 2009 should be done in a most conservative way.

Reply: We have revised the text accordingly, to discuss results of the temporal comparison with care, and as a suggestion for data interpretation, rather than as a conclusion. (see eg. L29)

Reviewer 2: Below are some more specific suggestions referring to location in the MS:

P337, L4 I think it's more accurate to say "sulphide oxidation is used as energy source".

Reply: L42; We changed the text to "Sulphide oxidation provides energy to thiotrophic bacteria…"

Reviewer 2: P337, L10 This expression is pretty strong. Does AOM always control methane emission "wherever sulphate and methane meet"? Actually this study itself is a good example of the fact that just he co-existence of sulfate and methane is not sufficient for AOM to control the fluxes.

Reply: We changed the text accordingly to:

L46; "AOM occurs where methane and sulphate meet and decreases methane emission to the hydrosphere across a wide range of environmental conditions (Knittel and Boetius, 2009)."

Reviewer 2: P337, L15. Eight references to prove one point is too many, please just cite the most relevant works.

Reply: L52; Done, number of references has been reduced to 5.

Reviewer 2: P344, L18. "Height" to be corrected as "heigth"
Reply: L235; We checked the dictionary, but "height" is spelled correctly

Reviewer 2: P347, L7. AOM decreases the pH, but why should the pH decrease downcore only show the absence of AOM? This sentence needs to be revised.
Reply: This is now clarified. (AOM does not decrease the pH.)
L296 "No sulphide production was detected in the upper 2 cm, matching the pore water data and microbial rate measurements, and pH showed a continuous decrease with depth."

Reviewer 2: P348, L5-15. This experiment is very interesting but I think this paragraph should be moved to section 4.1, where different hypotheses are discussed, perhaps under a heading such as "inhibiting substance in the fluids".
Reply: Here we would like to stick to the division in a Results and Discussion section, and in the Results describe the findings of the experiment, whereas in the Discussion in section 4.2 discuss the findings to falsify the hypothesis that subsurface fluids may contain toxic substances. However, we deleted one sentence from the Results section, which sounded like a discussion of the results

Reviewer 2: P350, 4.1.1. It seems like the biogenic muds are low in methane and sulfide, and oxygen as well. Is this observation close to a mud shrimp burrow? Maybe due to the mud shrimp activity this area is rich in oxidized forms of metals, such as iron(III) minerals, which can in turn titrate any sulfide fluxing from deep. Even though the sediment was not black does not mean that there is no FeS or metal sulfide formation. Actually nowhere in the manuscript the effects of metals on mud volcano biogeochemical processes are discussed. Are mud volcanoes low in metals? If not, their presence would significantly affect sulfide concentrations, among other things. This point needs to be elaborated and the spatial heterogeneity in this zone needs to be taken into account.
Reply: This is an interesting question, but we have not enough data to support such a discussion and can not speculate about the role of iron at Amon MV. However, we can state that cores from the biogenic mound region did not show black layers in the sediments as typical for iron-sulfide precipitation. Generally, depending on the mud volcano geological settings, iron can influence the biogeochemistry. For instance, sediments of the Arctic Haakon Mosby mud volcano were low in reactive iron (Lichtschlag et al., 2010) in contrast to the Dvurechenskii mud volcano (Black Sea) where iron plays a role in the benthic biogeochemistry (Lichtschlag et al., 2013 . However, a detailed discussion of the iron cycle is beyond the scope of our manuscript.

Lichtschlag, A., Felden, J., Brüchert, V., Boetius, A., and De Beer, D.: Geochemical processes and chemosynthetic primary production in different thiotrophic mats of the Håkon Mosby Mud Volcano (Barents Sea), Limnol. Oceanogr., 55, 931-949, 2010a.

Lichtschlag, A., Kamyshny Jr, Ferdelman, T.G., de Beer, D. (2013). "Intermediate sulfur oxidation state compounds in the euxinic surface sediments of the Dvurechenskii mud volcano (Black Sea)." Geochimica Et Cosmochimica Acta 105(0): 130-145.

Reviewer 2: P353, L8. The issue of temporal change between 2006 to 2009. The authors here and elsewhere in the manuscript seem to imply that this environment changes over the scales of years. My feeling is that shorter term changes are also possible, due to sudden changes in subsurface conditions and other related factors. Hence the change observed may be a short-term pulse. Also, spatial changes within each "zone" needs to be accounted for. Each zone has its peculiar heterogeneity, in one zone this is driven by heterogeneous outflow of seep fluid, in another by the mud shrimp burrows. I suggest that at the end of discussion part the authors need to elaborate on short-term temporal variation and spatial heterogeneity – and put the observed changes in 2006 and 2009 in this context.

Reply: We have revised the text carefully throughout to clarify our hypothesis that between 2006 and 2009 cooling occurred. Of course we have only achieved a two-point observation, by comparing results between two cruises to the same region in 2006 and 2009. Nevertheless, we think that this comparison over time is valuable, and consistent with the observations of spatial patterns in microbial activity. Between those years, we clearly see a decrease in temperature of subsurface fluids, and an erosion of surface mud blocks – as well as some changes in sulphate flux and microbial activity. This does not allow further speculation of in-between short term fluxes, as one would need observatories for continuous records of fluid flow and subsurface temperature for this. To avoid speculation, we kept this part relatively short and focused on the contribution to the general discussion of controls on microbial activity at mud volcanoes.